P 2.23 COMPARISON OF CDFS II WWMCA, CHANCES-RP AND MODIS CLOUD MASKS

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ABSTRACT

An improved method of retrieving cloud cover from two-channel geostationary meteorological satellite data has been developed. This method incorporates various visible and infrared radiance thresholding, including a new technique for infrared cloud detection: using topographic elevation and land cover databases to create stratified diurnal temperature curves. The results of this new cloud cover detection method are then compared with Moderate Resolution Imaging Spectroradiometer (MODIS) and World-Wide Merged Cloud Analyses (WWMCA) cloud masks.

1. INTRODUCTION

Clouds are among the most significant obstacles to satellite remote sensing of the earth's surface. To a cloud microphysicist, routine satellite observations of clouds might be desirable. But for an oceanographer measuring ocean temperatures during El Niño or an Air Force Lieutenant performing a battle damage assessment after a surgical air strike, clouds can negatively impact study results. Furthermore, many DoD mission-critical components (e.g., laser-guided bombs and night vision sights) do not operate reliably in the presence of clouds. To be of value, cloud data must be current and accurate, but such data are often difficult to obtain. Polar orbiting meteorological satellites (e.g., DMSP) cover a given location on earth only a few times a day. Geostationary meteorological satellites (e.g., GOES, Meteosat) currently cover more than 70 percent of the earth (containing 95 percent of the world's population) and can provide data on a sub-hourly basis. But with fewer channels available for cloud detection than with polar orbiting satellites, geostationary-based cloud detection algorithms have historically been less accurate and robust than those that use polar orbiting meteorological data.

The purpose of this paper is to demonstrate improvements in geostationary-based two-channel cloud detection algorithms developed by CIRA under the sponsorship of the DoD Center for Geosciences / Atmospheric Research (CG/AR). The time frame of results presented here is from 8 March through 17 April 2003, centering on the recent Operation Enduring Freedom over the Middle-Eastern region of the earth.

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2. BACKGROUND

Operationally, the Air Force Weather Agency (AFWA) uses a cloud analysis package called the World-Wide Merged Cloud Analyses (WWMCA), which is a sub-system of the Cloud Depiction and Forecast System (CDFS) II. WWMCA is a global, hourly, 24-km resolution product that incorporates five geostationary and four polar orbiting meteorological satellites. Further details of the CDFS II WWMCA can be found in Bieker et al. (2003). To better standardize our results, WWMCA data shown here have no manual bogusing applied and are considered "cloudy" when the data indicate an amount greater than fifty percent cloud.

The data presented here are visible and infrared (11 μm) imagery from the Climatological and Historical Analysis of Clouds for Environmental Simulations (CHANCES) database (Vonder Haar et al. 1995). CHANCES is a global, hourly, 5-km resolution, visible and infrared cloud and radiance database formed by merging geostationary and polar orbiting weather satellites. Most of the imagery over this sector is from the Meteosat-5 satellite that has a sub-satellite point of 63^{o} E. These data were assimilated into the CHANCES database format at a 1-hr and 5-km temporal and spatial resolution. Infrared image sectors were extracted for each hour, on the hour, and visible image sectors were extracted for the hours of 0500 UTC - 1300 UTC inclusive.

Improvements in CHANCES data processing include a new technique for infrared cloud detection. This new cloud test uses topographic elevation and land cover databases to create stratified diurnal temperature curves. These curves are compared to the actual change in infrared radiance to infer the presence or absence of cloud. These data are referred to as CHANCES-Regional Products (CHANCES-RP). Technical details of these improvements can be found in Reinke et al. (presented at this conference).

As part of NASA's Earth Observing System (EOS), the Moderate Resolution Imaging Spectroradiometer (MODIS) instrument on board NASA's TERRA and AQUA satellites has been collecting data since the years 2000 and 2002 respectively. This instrument measures the upwelling radiation in 36 narrow spectral channels at a nominal resolution of 1 km in a 2300-km swath under the satellite track. To better improve many of the MODIS products' accuracy, a cloud-masking algorithm has been developed. This algorithm uses 17 of MODIS' 36 spectral bands for its tests and is applied to every pixel of data to identify cloud contamination. The MODIS cloud detection algorithm is described in further detail by Ackerman et al. (1998). Because accurate cloud mask determination is our goal, the MODIS cloud mask product will be used as "truth" for this research.

3. METHODOLGY

MODIS cloud mask data over the Middle-Eastern region from 8 March through 17 April 2003 was obtained from the NASA Distributed Active Archive Center (DAAC). Each MODIS granule was then time and space matched with available CHANCES-RP and WWMCA data. Figure 1 illustrates how a MODIS granule (Fig. 1a) is matched to corresponding WWMCA (Fig. 1b) and CHANCES-RP (Fig. 1c) data. This matching of data was run on 526 daytime and 522 nighttime MODIS granules. This study includes only data that were matched within all three data sets. Frequency of cloud cover composites were then generated to visualize the results of the analyses.

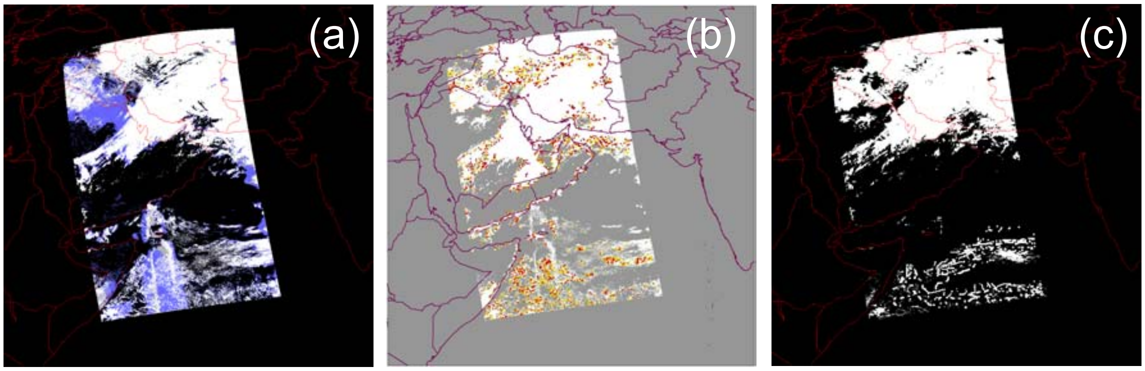

Figure 1. Example of MODIS (a) granule data matching with CDFS II WWMCA (b) and CHANCES-RP (c) datasets.

4. DAYTIME CLOUD MASK COMPARISON

An example of daytime cloud detection is shown in Figure 2. A visible (0.7 μm) Meteosat-5 image (Fig. 2a) is shown to provide background for the cloud detection methods presented. Corresponding MODIS (Fig. 2b), WWMCA (Fig. 2c) and CHANCES-RP (Fig. 2d) cloud mask results are very similar. A close look reveals sun glint contamination down the middle of the MODIS swaths. As one would expect, a forty-day climatology (Figure 3) comparison of cloud masks shows similar overall structures. WWMCA cloud mask data (Fig. 3a) mimics the MODIS cloud mask (Fig. 3d) over the northern mountainous regions and over the Ethiopian Highlands. Coastline contamination of the WWMCA cloud mask (due to the resolution of the product) is observed throughout the data. The CHANCES (Fig. 3b) and WWMCA cloud masks are very similar in structure and percentages.

Daytime cloud detection over desert regions has always been a troublesome task. Bright desert sands are often indistinguishable from clouds within visible satellite data. Cloud coverage within the WWMCA (Fig. 3a) and CHANCES (Fig. 3b) data sets is higher over desert regions (e.g., over Iraq). The incorporation of land use data into the CHANCES-RP cloud mask (Fig. 3c) (see Reinke et al. 2003 for more details) allows for a rigorous infrared thresholding that lowers the frequency of observed cloud over desert regions.

5. NIGHTTIME CLOUD MASK COMPARISON

Removing the visible channel from the cloud mask algorithm significantly reduces the accuracy in identifying cloud cover. It is therefore no surprise that nighttime cloud masking varies significantly between data sets. Figure 4 highlights these differences. The infrared Meteosat-5 image (Fig. 4a) shows that there is significant cloud cover over the Indian Ocean region. The MODIS cloud mask (Fig. 4b) indeed flags significant cloud over the oceanic regions while the WWMCA (Fig. 4c) and CHANCES (not shown) cloud masks miss most of the cloud over this region. CHANCES-RP (Fig. 4d) picks up significantly more cloud, though not as much as MODIS observes. These biases in cloud coverage are further exemplified when composited.

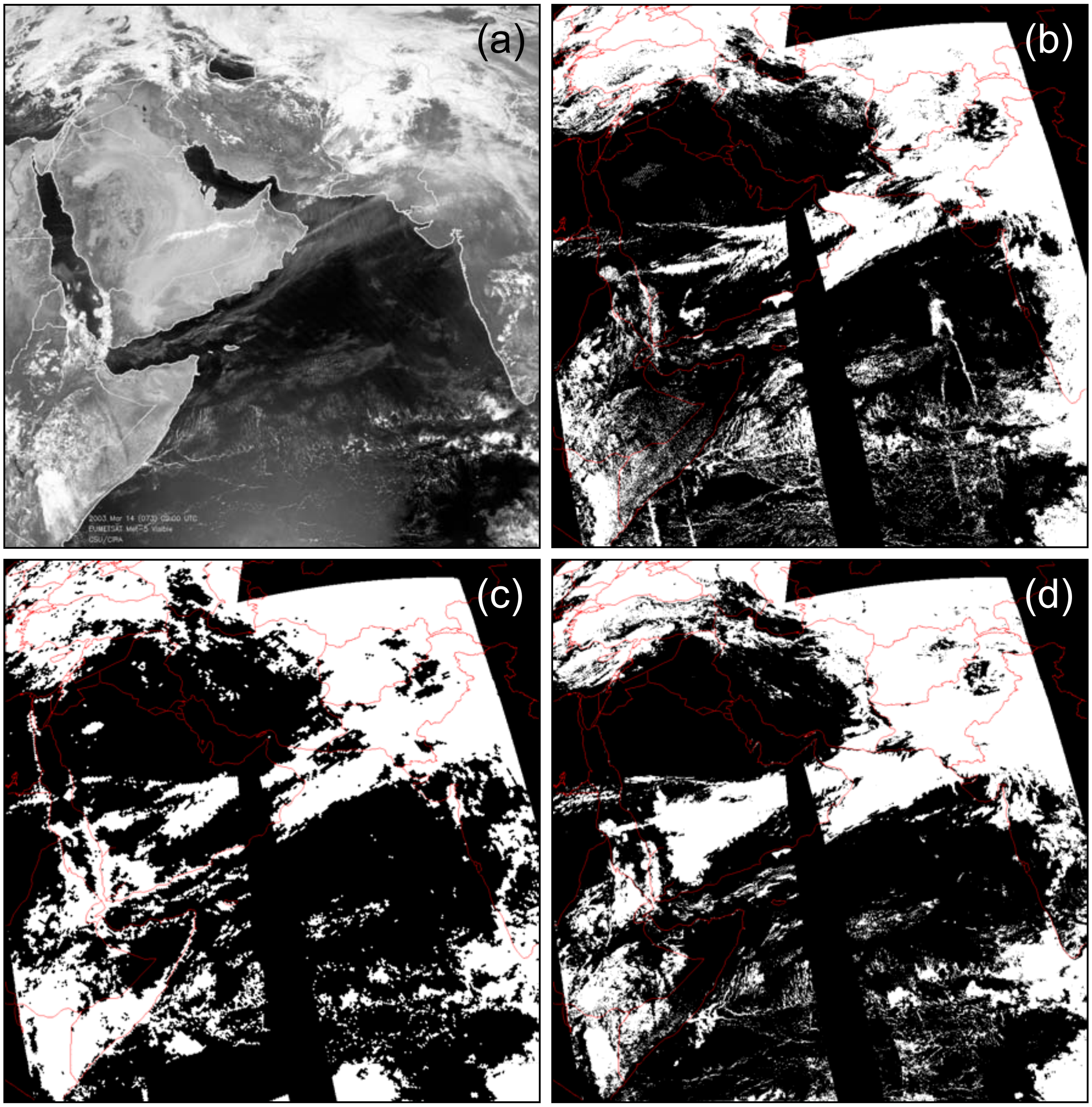

Figure 2. Visible (0.7 μm) Meteosat-5 image (a) from 14 March 2003 at 0900 UTC. MODIS cloud masks (b) from 0845 UTC (right swath) and 1025 UTC (left swath) along with corresponding CDFS II WWMCA cloud masks (c) and CHANCES-RP cloud masks (d).

Figure 5 shows nighttime cloud mask climatology comparisons for our forty-day period. Again, MODIS (Fig. 5d) flags a high percentage of cloud cover over water. By decreasing the water cloud threshold, CHANCES-RP (Fig. 5c) was able to flag approximately 30 percent more cloud cover over water in a pattern that matches the MODIS cloud distribution.

6. CONCLUSIONS AND FUTURE WORK

We have shown that it is possible to "tune" two-channel geostationary satellite data to match results derived from MODIS data. While this is a step in the right direction, more work is needed to determine what biases are present in the data sets and where "tuning"

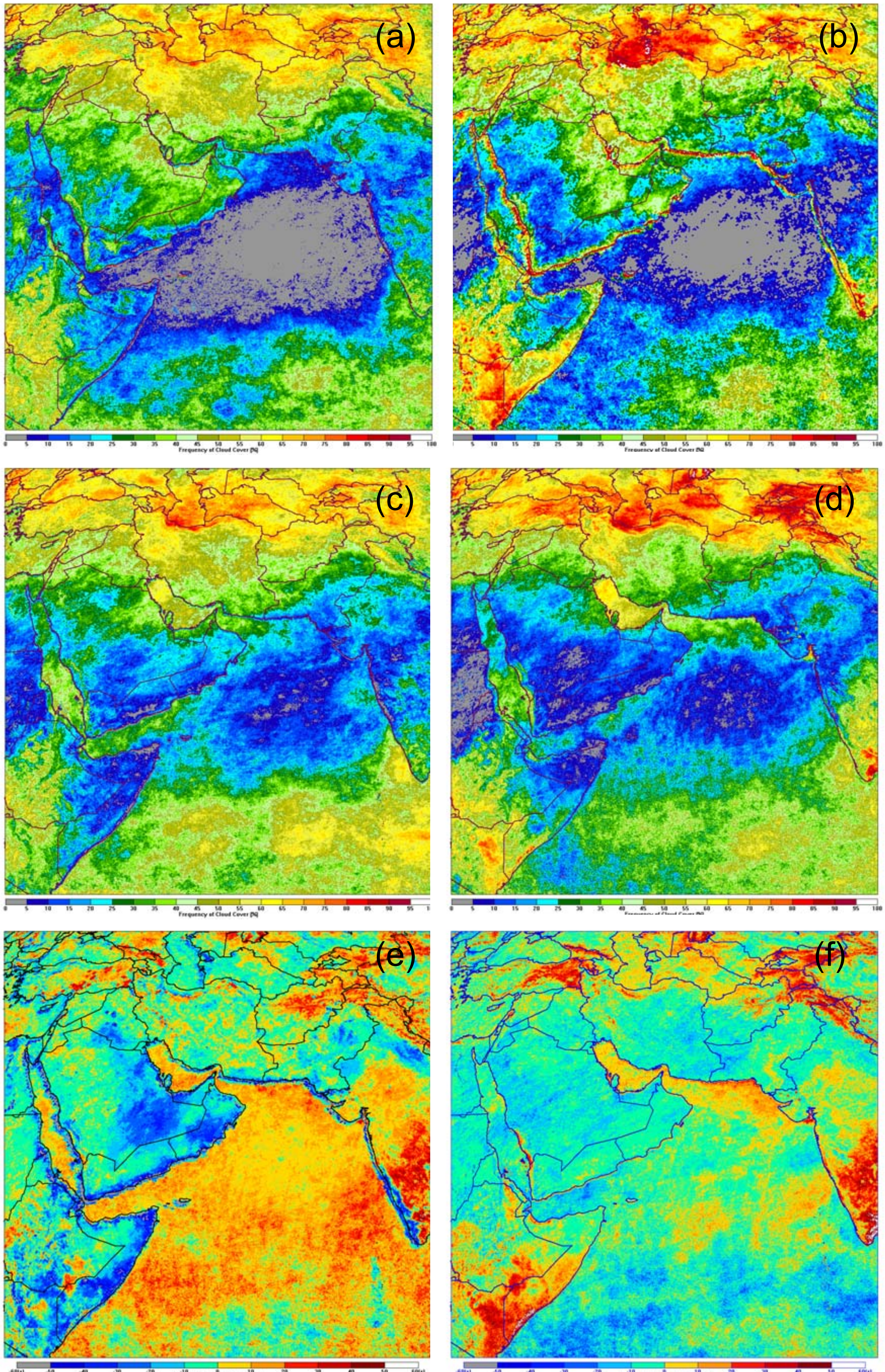

Figure 3. Forty-day frequency of occurrence (%) composites for daytime cloud cover (8 March through 17 April 2003) of CHANCES (a), CDFS II WWMCA (b), CHANCES-RP (c) and MODIS (d) cloud mask data. Percent difference in daytime cloud cover between MODIS (d) and CDFS II WWMCA (b) is shown in (e), while percent difference in daytime cloud cover between MODIS (d) and CHANCES-RP (c) is shown in (f) (note change in color table).

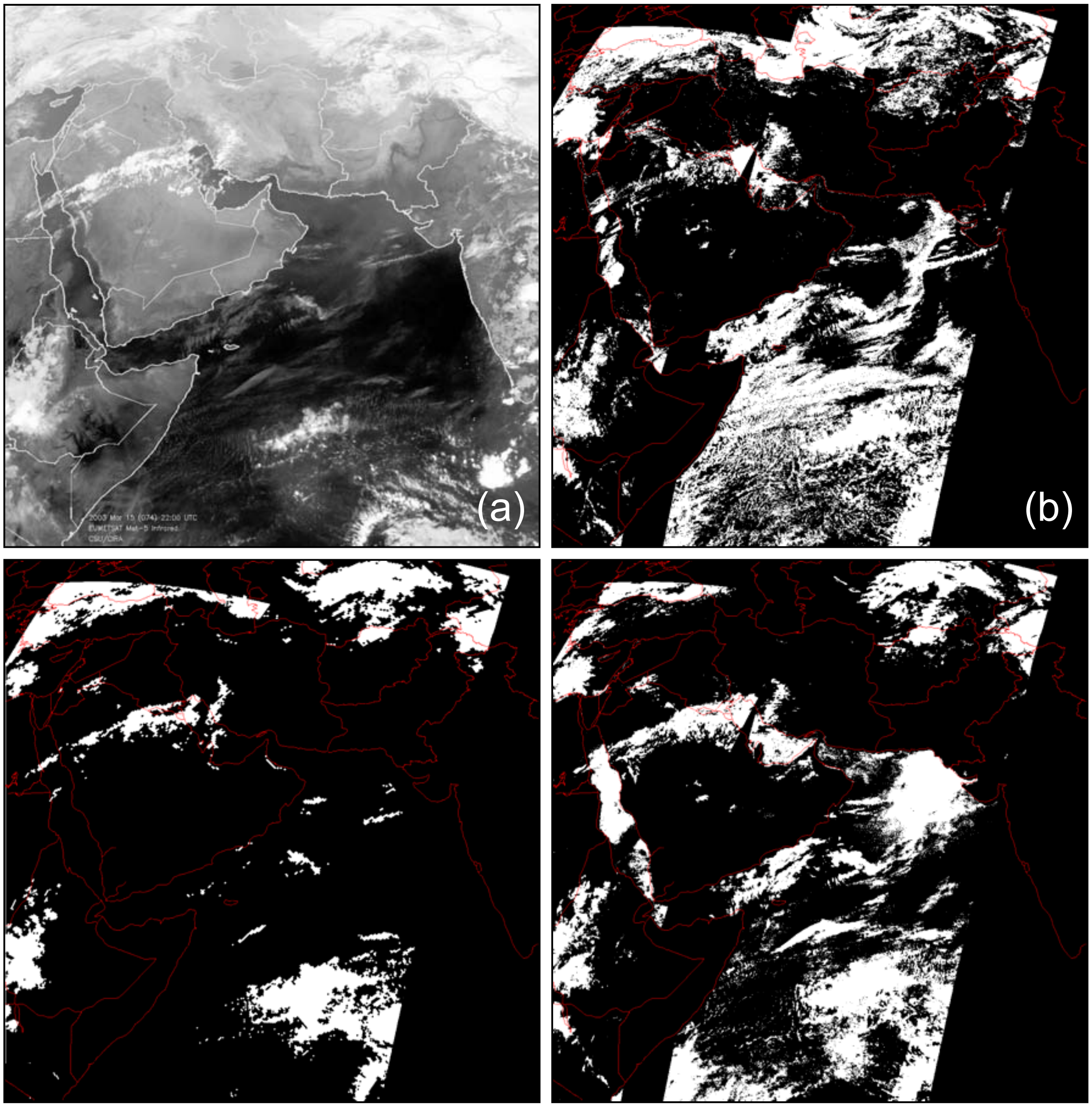

Figure 4. Infrared (11 μm) Meteosat-5 image (a) from 15 March 2003 at 2200 UTC. MODIS cloud masks (b) from 2140 UTC (right swath) and 2320 UTC (left swath) along with corresponding CDFS II WWMCA cloud masks (c) and CHANCES-RP cloud masks (d).

the cloud mask will improve overall results. One area to be addressed is the impact of thin cirrus on the MODIS cloud mask. Operationally, the MODIS cloud mask algorithm is being updated and improved upon periodically. Detection of cloud over land regions at night is still an issue that we will examine further.

One obvious difference between the cloud detection methods investigated here is the varying resolutions of the products. The effects of cloud contamination, including that due to coastlines and snow cover, can be greatly reduced by increasing the resolution of the cloud mask product.

Future work in this area will most likely involve applying this work to different seasonal and geographic locations around the globe. As more MODIS data are collected and archived, more robust climatologies can be composited which will help refine geostationary-based cloud detection.

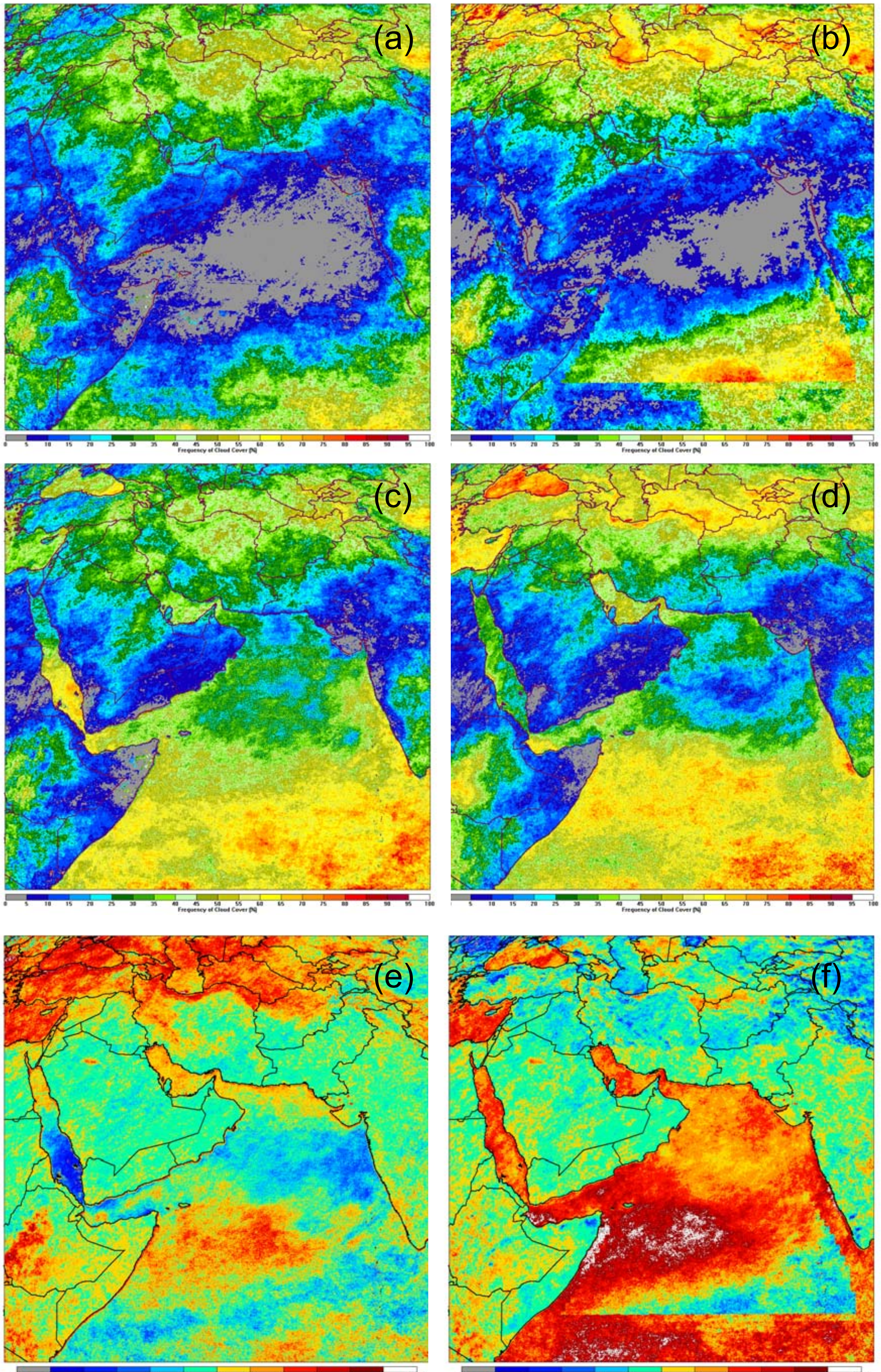

Figure 5. Forty-day frequency of occurrence (%) composites of nighttime cloud cover (8 March through 17 April 2003) of CHANCES (a), CDFS II WWMCA (b), CHANCES-RP (c) and MODIS (d) cloud mask data. Percent difference in nighttime cloud cover between MODIS (d) and CDFS II WWMCA (b) is shown in (e), while percent difference in nighttime cloud cover between MODIS (d) and CHANCES-RP (c) is shown in (f) (note change in color table).

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